Geographic Variation in Photoperiodic Induction of Pupal Diapause of *Neope goschkevitschii* MÉNÉTRIÈS (Lepidoptera, Satyridae)

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Introduction

Neope goschkevitschii is one of the commonest species and is distributed throughout Japan from Hokkaido to Kyushu. In order to establish such a wide range from north to south, this butterfly has evolved different life cycles and adapts itself to different climatic conditions. It has two generations in the lowlands at least in the Kanto Area and farther south, but only one generation in Hokkaido and in the highlands to the south of Hokkaido (FUKUDA *et al.*, 1972; TAKAHASHI, 1979).

The developmental rate of insects generally varies with temperature but diapause is controlled by daylength (DANILEVSKY, 1961; BECK, 1968). HIRAI (1966) showed that the pupal diapause of *N. goschkevitschii* in Tokyo was induced by a photoperiod of 10L14D during the larval stage, but not by 15L9D. SHIMA and ARAKAWA (1974) found that the Fukuoka strain showed a long-day type reaction with a critical daylength between 14 and 14.5 hrs.

In this paper were described the photoperiodic responses of four strains of *N. goschkevitschii* collected from different locations in the Japanese Islands.

Materials and Methods

Females were collected from Kaminokuni in Hokkaido (41°47′ N, 140°37′ E) in late July, 1980; the campus of Tsukuba University in Ibaraki (36°04′ N, 135°47′ E) in mid May, 1980; Kyoto (35°04′ N, 135°47′ E) in early May, 1980; Sanyo in Yamaguchi (34°06′N, 131°12′E) in early May, 1980 (Fig. 1). *N. goschkevitschii* has one generation each year in Kaminokuni and two generations in Tsukuba, Kyoto and Sanyo. All the collected females were spring-forms that had emerged from hibernating pupae.

The females from Kaminokuni, Kyoto and Sanyo oviposited on leaves of bamboo (*Pleioblastus* sp.) or bamboo grass (*Sasa* sp.) growing in the respective collecting sites. The Tsukuba strain oviposited on leaves of *P. chino* MAKINO, a primary food plant for the butterfly in the Kanto Area. Eggs were incubated under room-temperature and natural-light conditions. Larvae were reared in plastic vials (12 cm in diameter and 4 cm in height) under experimental photoperiods (Table 1). The temperature during the rearing period fluctuated between 22 and 28°C. The pupae were incubated at 25°C under natural-light conditions.

The number of emerging adults was recorded everyday. The pupae which did

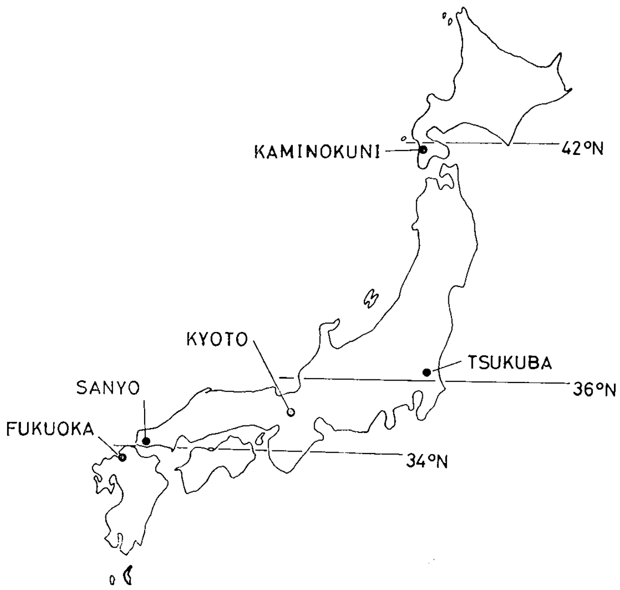

Fig. 1. Map showing the locations where adult females of *Neope goschkevitschii* were collected for the present study and for the previous study by SHIMA and ARAKAWA (1974).

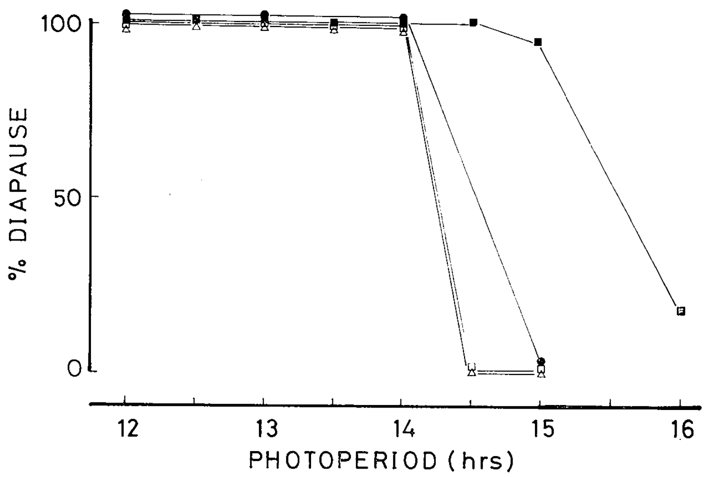

Fig. 2. Photoperiodic response curves in *Neope goschkevitschii* from different locations; closed squares = Kaminokuni, closed circles = Tsukuba, open squares = Kyoto and open triangles = Sanyo.

not emerge within 30 days at 25°C were regarded as diapausing, since non-diapause pupae emerged within 20 days at 25°C in each strain (TANI, unpubl.). Pupae which died within 30 days were not taken into account.

Results

Photoperiodic responses for the induction of pupal diapause in the four strains are shown in Table 1 and Fig. 2. Four strains showed long-day type reactions. In the Tsukuba, Kyoto and Sanyo strains, photoperiods longer than 14L10D during

Table 1. Effect of photoperiod on the induction of pupal diapause of *Neope goschkevitschii* from different locations.

	Photoperiod	No. of diapause pupae	No. of non-diapause pupae	Incidence of diapause (%)
Kaminokuni	16L8D	3	14	18
	15L9D	18	1	94
	14.5L9.5D	13	0	100
	14L10D	13	0	100
	13.5L10.5D	6	0	100
	13L11D	7	0	100
	12.5L11.5D	6	0	100
	12L12D	4	0	100
Tsukuba	15L9D	0	22	0
	14L10D	9	0	100
	13L11D	4	0	100
	12L12D	5	0	100
Kyoto	15L9D	0	6	0
	14.5L9.5D	0	3	0
	14L10D	4	0	100
	13.5L10.5D	5	0	100
	13L11D	30	0	100
	12L12D	15	0	100
Sanyo	15L9D	0	31	0
	14.5L9.5D	0	15	0
	14L10D	9	0	100
	13.5L10.5D	7	0	100
	13L11D	33	0	100
	12.5L11.5D	26	0	100
	12L12D	18	0	100

the larval stage prevented diapause, but all pupae diapaused under a photoperiod of 14L10D or shorter. Moreover, the last two strains averted diapause at 14.5L9.5D. The critical daylengths (50% diapause) of the Sanyo and Kyoto strains are therefore between 14 and 14.5 hrs and those of the Tsukuba strain between 14 and 15 hrs. A similar value was reported for the Fukuoka strain by SHIMA and ARAKAWA (1974). The Kaminokuni strain, however, showed a response different from the others. Diapause was induced under any photoperiods between 12L12D and 14.5L9.5D, and only one pupa did not diapause at 15L9D. Most pupae were free from diapause at 16L8D (Table 1). The critical daylength for the Kaminokuni strain was therefore between 15 and 16 hrs.

Discussion

The geographical variations of photoperiodic response in *N. goschkevitschii* showed a tendency similar to that reported in many other long-day insects (DANILEVSKY, 1961; BECK, 1968, etc.). The Sanyo, Kyoto and Tsukuba strains in the present study and the Fukuoka strain (SHIMA & ARAKAWA, 1974) are similar in that their critical daylengths lie between 14 and 15 hrs. This may be due to the similar latitudes of

their origin (34 to 36°N, Fig. 1). They may well be adapted to similar environmental conditions.

The critical daylength is closely related to the voltinism in each location. The maximum natural daylength in Tsukuba is about 15.5 hrs in June and the critical value (14.5 hrs) is exceeded from May to mid August (daylength is the time from sunrise to sunset plus civil twilights (BECK, 1968)). The first flight of spring forms is observed in Tsukuba from mid May to mid June. So it may be inferred that the larvae of the first generation produced by spring forms begin to grow from mid May in Tsukuba. They are exposed to long days of May to July and produce non-diapause pupae. The second flight of summer forms is observed from early August to early September so that the larvae of the second generation grow after August. They are then exposed to short days and produce diapausing pupae. The bivoltine life cycle is thus established. The life cycles in Kyoto, Sanyo and Fukuoka may similarly be explained by the relationship between the seasonal development and the critical daylength.

The Kaminokuni strain, on the other hand, has a critical daylength (between 15 and 16 hrs) longer than the others do. The maximum natural daylength in Kaminokuni is about 16 hrs in June and the daylength decreases to 15 hrs or shorter after mid July. The spring forms in Kaminokuni were collected in mid July, 1979 and late July, 1980. It is probable that the larvae of the first generation grow after June and are exposed to daylengths shorter than the critical one, so that they produce diapausing pupae. The life cycle thus becomes univoltine.

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要　　約

サトキマダラヒカゲ *Neope goschkevitschii* MÉNÉTRIÈS の蛹休眠に関する光周反応の地理的変異（谷　晋）

サトキマダラヒカゲ *Neope goschkevitschii* MÉNÉTRIÈS の蛹休眠に関与する光周反応の地理的変異を，上ノ国（北海道），筑波（茨城），京都および山陽（山口）の個体群について調べた．食餌植物としてアズマネザサ *Pleioblastus chino* MAKINO を用い，いろいろな光周条件下で幼虫を飼育した．その結果，すべての個体群は長日型の反応を示し，京都と山陽の個体群では 14.5 時間，筑波では 15 時間以上の日長ではすべて不休眠蛹になったが，14 時間以下の日長ではすべての個体群が休眠蛹を生じた．これらの個体群の臨界日長は 14 時間と 15 時間の間にあると考えられる．これに対し，上ノ国では 15 時間の日長でも 1 個体を除いてすべてが休眠したが，16 時間では多くが不休眠蛹となり他に較べて明らかに長い臨界日長を持つ．これらの臨界日長の差異はサトキマダラヒカゲが異なる気候条件に適応した結果と考えられる．